Chapter 1

Introduction

PET427, AZ

The U.S. Environmental Protection Agency (EPA) established the Clean Air Status and Trends Network (CASTNet) to provide data for determining relationships between emissions, air quality, deposition, and ecological effects. The network was mandated by the 1990 Clean Air Act Amendments (CAAA) to determine the effectiveness of promulgated emission reductions. CASTNet's objectives are to define the geographic distribution of pollutants and atmospheric deposition, detect and quantify trends in pollutants and deposition, and provide data on the dry deposition component of acid deposition and ground-level ozone concentrations. This report summarizes CASTNet monitoring activities and the resulting concentration and deposition data for 2002.

Overview

CASTNet originated from the CAAA, which mandated significant reductions in sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions from electric generating plants. Congress recognized the need to track real-world environmental results as the emission reductions were implemented. As a result, the CAAA also formalized the establishment of a nationwide network for monitoring air quality and acid deposition. To meet this monitoring objective, the EPA established CASTNet, which has since evolved into a robust, national, long-term monitoring program that measures changes in air quality and atmospheric deposition over broad geographic regions of the United States. The primary objectives for CASTNet are to:

- Monitor the status and trends in regional air quality and atmospheric deposition;
- Provide information on the dry deposition component of total acid deposition, ground-level ozone (O_3), and other forms of atmospheric gaseous and aerosol pollution; and
- Assess and report on geographic patterns and long-term, temporal trends in ambient air pollution and acid deposition.

CASTNet is the nation's primary source of atmospheric data on the dry deposition component of total acid deposition, rural ground-level ozone, and other forms of atmospheric pollution.

Table 1-1. Network Summary Table

CASTNet Air Quality Network	
Initiated	1986*
Number of Sites (as of December 2002)	87 (84 standard sites, 2 collocated sites, and 1 day/night site)
Sponsoring Federal Agencies	EPA-54 sites NPS-30 sites
Sampling Schedule	7-day (168 hours) Tuesday to Tuesday
Ambient Measurements	**Gaseous:** sulfur dioxide (SO_2) nitric acid (HNO_3) ozone (O_3)
	Particulate: sulfate (SO_4^{2-}) nitrate (NO_3^-) ammonium (NH_4^+) calcium (Ca^{2+}) sodium (Na^+) magnesium (Mg^{2+}) potassium (K^+)
Meteorological Measurements (as hourly averages)	Temperature at 9 meters
	Delta Temperature between 2 and 9 meters
	Solar Radiation
	Relative Humidity
	Precipitation
	Scalar Wind Speed
	Vector Wind Speed
	Wind Direction
	Standard Deviation of Wind Speed within the hour (Sigma Theta)
	Rate of Flow through the Filter Pack
	Surface Wetness
Information on Land Use and Vegetation	Site Surveys
	Site Operator Observations Vegetation Type Percent Green Leaf Out
	Leaf Area Index (LAI)
Trends	Concentrations of Sulfur and Nitrogen Species and Cations
	Deposition of Sulfur and Nitrogen
	Ozone Concentrations

*   The National Dry Deposition Network (NDDN) was established in 1986 and field measurements began in 1987. With the passage of the Clean Air Act Amendments of 1990, NDDN was entirely subsumed by CASTNet in mid-1991.

The National Park Services (NPS) is responsible for the protection and enhancement of air quality related values in national parks and wilderness areas. Consequently, NPS established air quality monitoring stations as part of its air quality program. In 1994 NPS and EPA entered into a partnership agreement to operate CASTNet sites. As of the end of 2002, NPS sponsored 30 sites in CASTNet. NPS and EPA are responsible for operating their sites under a common set of quality assurance (QA) standards and similar monitoring and data validation protocols. The measurements from the NPS sites are merged into a single database and delivered to EPA.

CASTNet operates in partnership with other rural long-term monitoring networks such as the National Atmospheric Deposition Program / National Trends Network (NADP/NTN). Together these networks allow for a regional assessment of total (dry + wet) acid deposition throughout the United States. EPA relies on these long-term monitoring networks to generate the data and information used to assess the effectiveness of national air pollution control efforts under several different mandates, including Title IX of the CAAA, the National Acid Precipitation Assessment Program (NAPAP), the Government Performance and Results Act, and the United States - Canada Air Quality Agreement.

The principal component of CASTNet is the measurement of atmospheric sulfur and nitrogen pollutants and cations at rural sites across the United States. In addition, nearly all CASTNet sites include continuous measurements of O_3 concentrations and meteorological conditions together with

CASTNet is the principal source of information on dry deposition throughout the United States. Dry deposition is a component of acidic deposition, which occurs when emissions of SO_2 and NO_x react with particles, water droplets, oxygen, and oxidants to form acidic compounds. Dry deposition represents a variety of meteorological, chemical, and biological processes that transport and deposit these acidic compounds to the environment. Wet deposition occurs when precipitation removes the acidic compounds from the atmosphere and deposits them to the environment. CASTNet provides information on trends in dry, wet, and total deposition of atmospheric sulfur and nitrogen species.

supporting information on vegetation and land use (Table 1-1).

The meteorological, vegetation, and land use data are used as input to the Multi-Layer Model (MLM), a mathematical model that simulates atmospheric dry deposition processes (Meyers *et al.*, 1998; and Finkelstein *et al*., 2000). The MLM is used to calculate deposition velocities (V_d), which are combined with the concentration measurements to estimate dry deposition of gaseous and aerosol pollutants.

Prior to CASTNet, EPA operated the National Dry Deposition Network (NDDN), which began operation in 1986. NDDN operated approximately 50 sites that became the core CASTNet sites when the NDDN was incorporated into CASTNet in 1991. NDDN also estimated dry deposition using measured air pollutant concentrations and modeled V_d.

This report summarizes the results of CASTNet measurements collected during 2002 and includes the following: annual and quarterly mean concentration data for atmospheric gaseous and particulate sulfur and nitrogen species and particulate cations along with an analysis of trends in annual concentrations over the period 1990 through 2002; estimates of dry, wet, and total deposition and their trends over the 13-year period; rural, ground-level ozone data for 2002 and trends over the 13 years; and an assessment of data quality. All CASTNet measurements are based on standard temperature and pressure (STP). However, for reporting purposes, the CASTNet filter data have been converted to local conditions in this report (Chapter 5). Previous CASTNet Annual Reports for the years 1998 - 2001 can be found on the EPA web site: www.epa.gov/castnet/library.html.

Network Description

The locations of CASTNet sites as of December 2002 are shown in Figure 1-1. Eighty-four sites were operational. All sites were equipped with filter packs for measurement of pollutant concentrations and estimation of dry deposition. Eighty-two sites measured O_3, although two solar-powered sites in New York and Vermont had only sporadic data capture and only during the ozone season. Collocated sampling systems were operated at two dry deposition sites for the purpose of estimating network precision. Collocated systems were operated at Mackville, KY (MCK131/231, KY) and at Rocky Mountain National Park, CO (ROM206/ROM406, CO). The two national park sites are operated
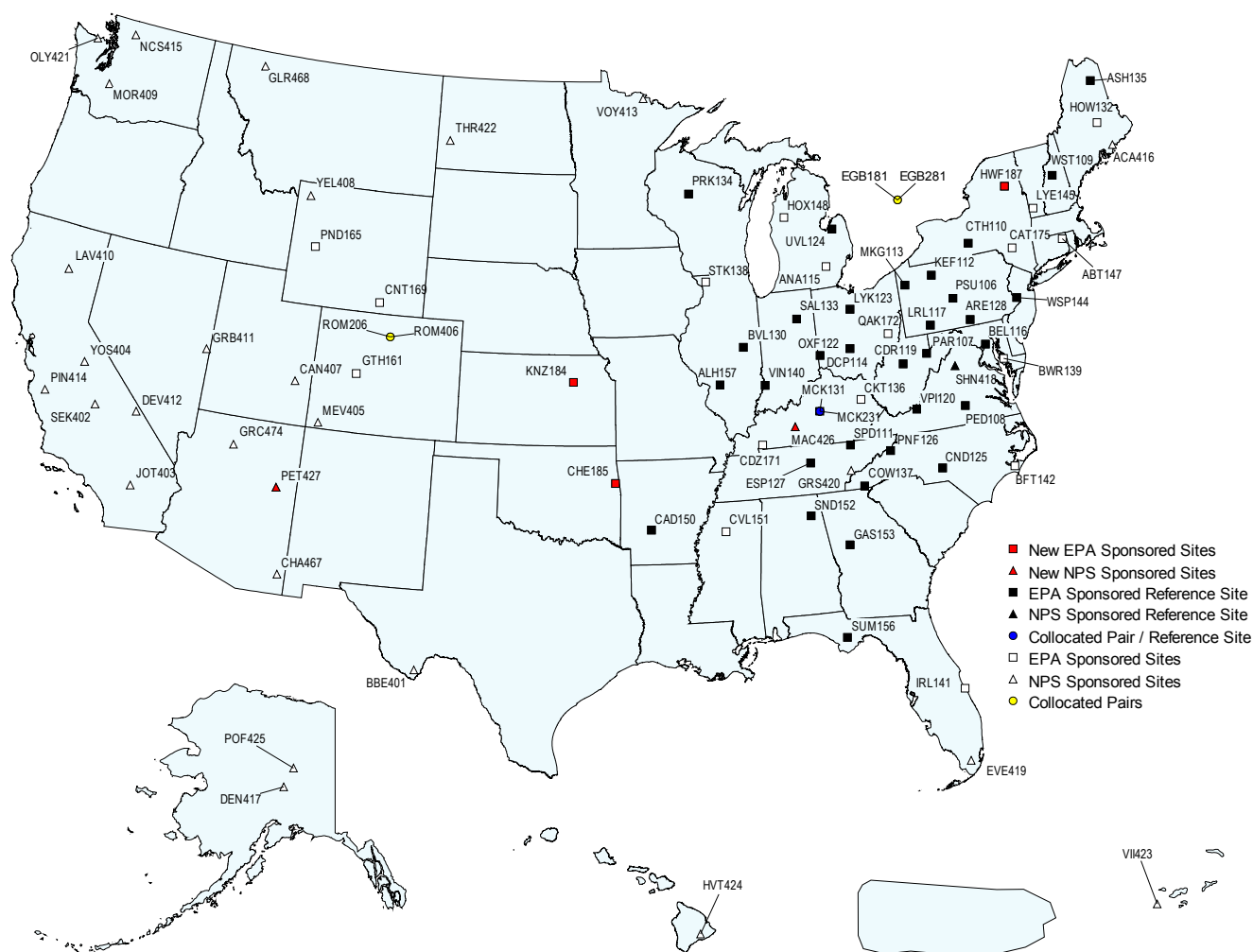
independently. ROM206 is operated on behalf of EPA and ROM406 on behalf of NPS. Appendix A provides the location and operational characteristics of each site by state, including information on start date, latitude, longitude, elevation, and the types of measurements taken at each site.

NADP/NTN operated wet deposition sampling systems at 15 EPA-sponsored and 30 NPS-sponsored CASTNet sites. This effort included analysis and reporting of precipitation chemistry samples. NADP/NTN also operated wet deposition sampling systems at other locations near virtually every CASTNet site. The NADP/NTN database represents the primary source of information on wet deposition across the United States. The combination of CASTNet and NADP/NTN data provides information on total (dry + wet) deposition. More information about NADP/NTN may be found on their web site: http://nadp.sws.uiuc.edu.

CASTNet operated eight visibility ($PM_{2.5}$) sites beginning in 1993 and ending in 2001. The CASTNet $PM_{2.5}$ sampling systems were replaced by Interagency Monitoring of Protected Visual Environments (IMPROVE) systems. Six of the eight sites were collocated with dry deposition sites. The other two sites were operated on behalf of IMPROVE with no additional measurement systems. IMPROVE systems were also operated at 29 of the 30 NPS-sponsored CASTNet sites. Information about IMPROVE can be found on their web site: http://vista.cira.colostate.edu/improve/.

Figure 1-1. CASTNet Sites as of December 2002

Legend:
- ■ New EPA Sponsored Sites
- ▲ New NPS Sponsored Sites
- ■ EPA Sponsored Reference Site
- ▲ NPS Sponsored Reference Site
- ● Collocated Pair / Reference Site
- □ EPA Sponsored Sites
- △ NPS Sponsored Sites
- ● Collocated Pairs

State	Site ID	Station	State	Site ID	Station	State	Site ID	Station
AL	SND152	Sand Mountain	KY	CDZ171	Cadiz	OH	QAK172	Quaker City
AK	DEN417	Denali National Park		CKT136	Crockett	OK	CHE185	Cherokee Nation
	POF425	Poker Flats Research Range		MAC426	Mammoth Cave National Park	ON	EGB181	Egbert, Ontario, Canada
AZ	CHA467	Chiricahua National Monument		MCK131	Mackville	PA	ARE128	Arendtsville
	GRC474	Grand Canyon National Park	ME	ACA416	Acadia National Park		KEF112	Kane Experimental Forest
	PET427	Petrified Forest National Park		ASH135	Ashland		LRL117	Laurel Hill State Park
AR	CAD150	Caddo Valley		HOW132	Howland		MKG113	M.K. Goddard State Park
CA	DEV412	Death Valley National Monument	MD	BEL116	Beltsville		PSU106	Pennsylvania State University
	JOT403	Joshua Tree National Monument		BWR139	Blackwater National Wildlife Refuge	TN	ESP127	Edgar Evins State Park
	LAV410	Lassen Volcanic National Park	MI	ANA115	Ann Arbor		GRS420	Great Smoky Mountains National Park
	PIN414	Pinnacles National Monument		HOX148	Hoxeyville		SPD111	Speedwell
	SEK402	Sequoia National Park		UVL124	Unionville	TX	BBE401	Big Bend National Park
	YOS404	Yosemite National Park	MN	VOY413	Voyageurs National Park	UT	CAN407	Canyonlands National Park
CO	GTH161	Gothic	MS	CVL151	Coffeeville	VT	LYE145	Lye Brook
	MEV405	Mesa Verde National Park	MT	GLR468	Glacier National Park	VI	VII423	Virgin Islands National Park
	ROM206	Rocky Mountain National Park	NV	GRB411	Great Basin National Park	VA	PED108	Prince Edward
	ROM406	Rocky Mountain National Park	NH	WST109	Woodstock		SHN418	Shenandoah National Park
CT	ABT147	Abington	NJ	WSP144	Washington's Crossing		VPI120	Horton Station
FL	EVE419	Everglades National Park	NY	CAT175	Claryville	WA	MOR409	Mount Rainier National Park
	IRL141	Indian River Lagoon		CTH110	Connecticut Hill		NCS415	North Cascades National Park
	SUM156	Sumatra		HWF187	Huntington Wildlife Forest		OLY421	Olympic National Park
GA	GAS153	Georgia Station	NC	BFT142	Beaufort	WV	CDR119	Cedar Creek State Park
HI	HVT424	Hawaii Volcanoes National Park		CND125	Candor		PAR107	Parsons
IL	ALH157	Alhambra		COW137	Coweeta	WI	PRK134	Perkinstown
	BVL130	Bondville		PNF126	Cranberry	WY	CNT169	Centennial
	STK138	Stockton	ND	THR422	Theodore Roosevelt National Park		PND165	Pinedale
IN	SAL133	Salamonie Reservoir	OH	DCP114	Deer Creek State Park		YEL408	Yellowstone National Park
	VIN140	Vincennes		LYK123	Lykens			
KS	KNZ184	Konza Prairie		OXF122	Oxford			

Both EPA-sponsored sites and NPS-sponsored sites operate O_3 analyzers. CASTNet QA procedures for the EPA O_3 analyzers are different from the EPA requirements for State and Local Monitoring Stations (SLAMS) monitoring as described in 40 CFR Part 68, Appendix A (EPA, 1998). On the other hand, the QA procedures for the O_3 analyzers at NPS sites meet the SLAMS requirements. Consequently, O_3 data from EPA-sponsored sites cannot be used to gauge compliance with National Ambient Air Quality Standards (NAAQS) for ozone. The operation of two independent, collocated O_3 analyzers at ROM206/406 provides an opportunity to evaluate the precision of the two systems that are operated with different QA and quality control (QC) procedures. The results from the collocated O_3 sampling during 2002 show a mean absolute relative percent difference (MARPD) between the two data sets of 4.43 percent. This result demonstrates that the O_3 measurements are essentially equivalent. Based on the CASTNet siting criteria, the O_3 measurements are generally considered regionally representative, and therefore, able to define geographic patterns of rural ozone across most of the United States. These data are appropriate for use in establishing general status and trend patterns in regional O_3 levels and for making general statements regarding the extent to which rural areas exceed the concentration levels mandated by the NAAQS.

One of the CASTNet sites is located in Egbert, Ontario, Canada (EGB181, ON). At this site, three sampling systems were operated on behalf of EPA. One system measured weekly daytime (0800 to 2000) concentrations and one system operated weekly nighttime (2000 to 0800) concentrations. The third system was a standard weekly CASTNet filter pack. These systems provide the means to compare results from CASTNet with the Canadian Air and Precipitation Monitoring Network (CAPMoN). CAPMoN collects daily filter samples using the same measurement methods. The CASTNet data also provide information to gauge differences in the weekly concentrations versus the separate daytime/nighttime values and also to investigate uncertainties in dry deposition estimates. O_3 is not measured by EPA at Egbert.

Table 1-2 summarizes significant operational events and decisions for 2002. More details on the history of the network can be found in previous annual reports.

Five new sites were added to the network during 2002. New sites were established at Konza Prairie, KS (KNZ184, KS), Stilwell, OK (CHE185, OK), Huntington Wildlife Forest, NY (HWF187, NY), Mammoth Cave National Park, KY (MAC426, KY), and Petrified Forest National Park, AZ (PET427, AZ). The first three sites are sponsored by EPA and the last two by NPS. Other agencies are also cooperating with EPA with the operation of the three sites. Site operators and site logistics are provided by the Long Term Ecological Research (LTER) Program for KNZ184, by the Cherokee Nation for CHE185, and by the State University of New York (SUNY) for HWF187.

Table 1-2. 2002 Significant Operational Events

January
Photographic documentation of the sites began.
Revision 0.0 of the CASTNet QAPP officially approved by EPA.
February
Mr. Kemp Howell assumed the role of Project Manager for CASTNet.
New junction boxes designed to reduce faulty connection problems installed at R.M. Young sites.
March
Nephelometer operation at QAK172, OH transferred to IMPROVE.
KNZ184, KS became operational.
April
CHE185, OK became operational.
Data Quality Objectives Process Overview submitted.
Site designation for Hoxeyville, MI changed from HOX149 to HOX148.
Day/night sampling at Egbert, Ontario renamed EGB281 to indicate collocation.
May
Stainless steel dust screens installed on humidity sensors at R.M. Young sites.
HWF187, NY became operational.
Finalized and distributed CASTNet Quality Management Plan (QMP).
June
Five Data Operations SOP approved. CDMSA demonstrated to EPA
July
A "floor-to-ceiling" audit of CASTNet property conducted by EPA and the Defense Contract Management Agency at MACTEC's Gainesville, FL location.
NPS site MAC426, KY became operational.
Plant speciation profiles for nine NPS sites and two EPA sites added to the CASTNet database for inclusion in deposition simulations by the Multi-Layer Model.
August
Last CASTNet-sponsored nephelometer discontinued at CDZ171, KY.
September
NPS site PET427, AZ became operational.
October
MACTEC upgraded the CASTNet server from Novell® NT Server 4.0™ to Windows® 2000.
Version 0.01 of the CASTNet QAPP distributed.
MACTEC Engineering and Consulting, Inc. became the official name of Harding ESE.

Methods

Methods employed by CASTNet were described in the CASTNet Quality Assurance Project Plan (QAPP) (Harding ESE, 2001) and previous annual reports. This section summarizes information on field operations; laboratory operations; methods of data analysis, including discussion of the MLM, flux calculation and aggregation procedures, and reference sites used in the trend analyses; and the CASTNet database.

Figure 1-2. Diagram of Three-Stage Filter Pack
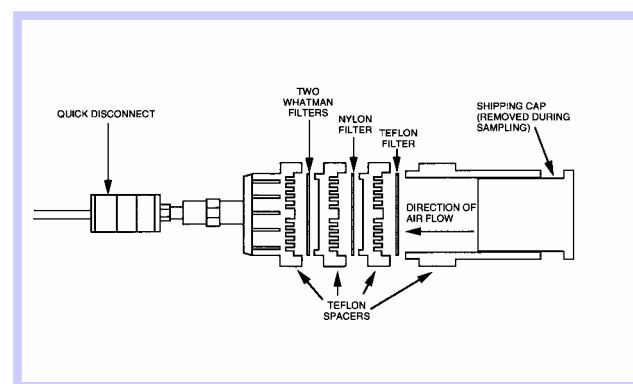
Field Operations

Meteorological variables and O_3 concentrations were recorded continuously and reported as hourly averages. Atmospheric sampling for sulfur and nitrogen species was integrated over weekly collection periods using an open-face, three-stage filter pack (Figure 1-2). In this approach, particles and selected gases were collected by passing air at a controlled flow rate through a sequence of Teflon®, nylon, and Whatman filters. The Teflon® filter removed particulate SO_4^{2-}, NO_3^-, NH_4^+, and certain cations; and the nylon filter removed HNO_3. The

Whatman filter, a cellulose fiber base impregnated with potassium carbonate (K_2CO_3), removed SO_2. Two Whatman filters were used. In practice, a fraction (usually < 20%) of ambient SO_2 is captured on the nylon filter as SO_4^{2-}. The nylon filter SO_2 and Whatman filters SO_2 (as SO_4^{2-}) were summed to provide weekly average concentrations. The nylon filter HNO_3 was converted to NO_3^- and added to the NO_3^- collected on the Teflon® filter to provide weekly total NO_3^- concentrations.

Filter packs were prepared and shipped to the field weekly and exchanged at each site every Tuesday. Filter pack sampling and O_3 measurements were performed at 10 meters (m) using a tilt-down aluminum tower. Filter pack flow was maintained at 1.50 liters per minute (Lpm) at sites having higher concentrations of analytes (generally eastern sites) and 3.00 Lpm for sites with lower concentrations (generally western sites) for standard conditions of 25 degrees Celsius (°C) and 760 millimeters (mm) of mercury (Hg) with a mass flow controller (MFC).

Ambient O_3 concentrations were measured via ultraviolet (UV) absorbance. Zero, precision [90 parts per billion (ppb)], and span (400 ppb) checks of the O_3 analyzer were performed every Sunday using an internal O_3 generator.

Each CASTNet site employed meteorological equipment to measure temperature, delta temperature, relative humidity, solar radiation, scalar and vector wind speed, sigma theta, surface wetness, and precipitation. CASTNet meteorological measurements are described in the QAPP (Harding ESE, 2001). The data were archived as hourly averages.

All field equipment was subjected to semiannual inspections and multipoint calibrations using standards traceable to the National Institute of Standards and Technology (NIST). Results of field calibrations were used to assess sensor accuracy and flag, adjust, or invalidate field data. In addition, audits were performed every other year by Air Resource Specialists, Inc. (ARS). Results of 2002 QA activities and an assessment of data quality are discussed in Chapter 6.

Laboratory Operations

Filter pack samples were loaded, shipped, received, extracted, and analyzed by MACTEC Engineering and Consulting, Inc. (MACTEC) personnel at the Gainesville, FL laboratory.

Upon receipt the filters were placed in appropriately labeled bottles that serve as both extraction and storage containers for the extracts and extracted filters. Prior to analysis, Teflon® filters were extracted in deionized (DI) water with a shaking before and after sonication. The extraction bottles were then stored were then stored for eight hours at 4 °C. The Teflon® extracts were analyzed for SO_4^{2-}, NO_3^-, NH_4^+, Ca^{2+}, Na^+, Mg^{2+}, and K^+. Nylon filters were extracted in a DI water solution containing 0.17 percent hydrogen peroxide and 0.30 percent of 2N NaOH. The nylon filter extraction bottles containing the filters and extracts were shaken and then stored for eight hours at 4 °C prior to analysis. The nylon extracts were analyzed for SO_4^{2-} (reported as SO_2) and NO_3^-. Whatman filters were extracted in a DI water solution containing 0.17 percent hydrogen peroxide and 0.25 percent concentrated hydrochloric acid (HCl). Extraction of the Whatman filters followed the procedure used for Teflon® filters with a

shaking before and after sonication. Analysis for SO_4^{2-} began after the extracts had been stored for eight hours at 4 °C. The extracts were analyzed for SO_4^{2-} and NO_3^- by ion chromatography (IC); for NH_4^+ by the automated indophenol method; and four cations (Ca^{2+}, Na^+, Mg^{2+}, and K^+) using inductively coupled plasma – atomic emission spectroscopy (ICP-AES). All analyses were completed within 72 hours of filter extraction.

Results of all valid analyses were stored in the laboratory data management system [Chemical Laboratory Analysis and Scheduling System (CLASS™)]. Atmospheric concentrations were then calculated based on the mass of each analyte in each filter extract and the volume of air sampled.

Methods of Data Analysis

Modeling Dry Deposition

The original network design was based on the assumption that dry deposition or flux could be estimated as the linear product of ambient concentration (C) and V_d:

$$Flux = \overline{C} \; x \; \overline{V_d}$$

where the overbars indicate an average over a suitable time period (e.g., 1 hour).

The influence of meteorological conditions, vegetation, and chemistry is simulated by V_d. Dry deposition processes are modeled as resistances to deposition. A general form of the resistance model is:

$$R = R_a + R_b + R_c = \frac{1}{V_d}$$

R_a signifies aerodynamic resistance or the resistance to turbulent vertical transport; R_b is the boundary layer resistance to vertical transport in a very shallow layer adjacent to the surface; and R_c is the canopy resistance or the resistance to pollutant uptake by the vegetative canopy. R_c simulates several physical and chemical processes. A resistance model specific to the MLM is given in Figure 1-3.

A schematic of the MLM in Figure 1-3 shows the relationships among the various resistances and illustrates the meteorological and other data that are required as model input. For example, temperature, relative humidity (RH), solar radiation (SR), and leaf area index (LAI) data are required to calculate the stomatal resistance, which is a component of the overall canopy resistance. Similarly, wind speed and sigma theta data are required to estimate the aerodynamic resistance.

The MLM software code was updated in 2002 according to established version control procedures (Harding ESE, 2001). The most recent software is designated as Version 2.31.

The meteorological variables used to determine R_a and R_b were obtained from the 10-m meteorological tower at each of the sites, which is normally located in a clearing over grass or another low vegetative surface. Data on vegetative species, LAI, and percent green leaf out were obtained from site surveys and observations by the site operator.

LAI measurements were taken during 1991, 1992, and 1997 at times of summer maximum leaf out. Vegetation data for 11 sites were added to the MLM database in 2001. Data for

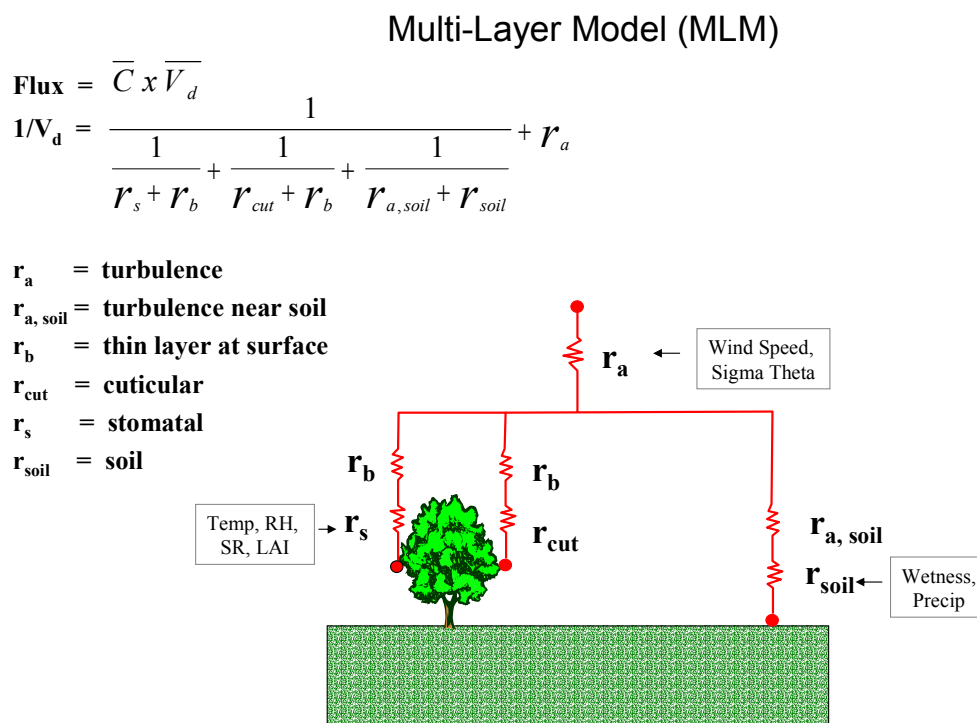the three EPA-sponsored sites (KNZ184, KS; CHE185, OK; and HWF187, NY) installed in 2002 were added to support the model calculations presented in this report. Additionally, the vegetation data for IRL141, FL were updated. LAI values used in the MLM were extrapolated from these measurements and estimates using percent leaf out observations. The resistance terms (R_a, R_b, and R_c) were calculated for each chemical species and major vegetation/surface type for every hour with valid meteorological data. The V_d for a site was then calculated as the area-weighted V_d over vegetation types within 1.0 kilometer (km) of the site.

Deposition Flux Calculations and Aggregations

Hourly deposition fluxes were calculated as the product of the hourly V_d obtained from the MLM and the corresponding hourly concentration. Hourly concentrations were obtained from the weekly filter pack results and measured hourly O_3 concentrations; all hourly concentrations during a filter pack sampling period were assumed to be equal to the filter pack sample concentration and constant for the duration of the sample.

MLM calculations are not one-dimensional, but applied through a 20-layer canopy in which model parameters are modified by the redistribution of heat, momentum, and pollutants.

Figure 1-3. Multi-Layer Model

Multi-Layer Model (MLM)

$$\text{Flux} = \overline{C} \; x \; \overline{V}_d$$

$$1/V_d = \cfrac{1}{\cfrac{1}{r_s + r_b} + \cfrac{1}{r_{cut} + r_b} + \cfrac{1}{r_{a,soil} + r_{soil}}} + r_a$$

r_a = turbulence
$r_{a,soil}$ = turbulence near soil
r_b = thin layer at surface
r_{cut} = cuticular
r_s = stomatal
r_{soil} = soil

Weekly deposition fluxes are the sum of the valid hourly fluxes for a standard deposition week, divided by the ratio of valid hourly fluxes to the total number of hours in the standard week to account for missing or invalid values. A standard deposition week is defined as the 168-hour period from 0900 Tuesday to 0900 the following Tuesday. For some weeks, the filter pack sampling period did not correspond exactly with the standard deposition week, resulting in some deposition weeks being derived from hourly concentrations from more than one filter pack sample. A weekly deposition flux is considered valid if it is comprised of valid hourly values for at least 70 percent of the 168-hour week (i.e., 118 hours).

Similarly, quarterly fluxes are calculated from weekly values, and are considered valid if they are comprised of valid weekly values for approximately 70 percent of the weeks during the 13 week period. Also, the midpoint of the sampling week had to occur within the quarter to be included as part of the respective quarterly average. Annual values are calculated from quarterly values, and are considered valid if they are comprised of at least three valid quarters.

Quarterly and annual mean concentrations are aggregated based on the same requirements as the flux aggregations. However, the concentrations are averaged while the fluxes are summed.

Reference Sites Used in Trend Analyses

One of the major goals of CASTNet is to monitor trends in air quality and deposition. Figure 1-1 shows of the locations of the 34 eastern sites used to perform trend analyses of pollutant concentrations from 1990 through 2002. The reference sites were selected using criteria similar to those used by EPA in its National Air Quality and Emissions Trends Report (2000). Sites with complete data for 11 of the 13 years were selected. Missing quarterly data were interpolated from adjacent quarterly data, e.g., first quarter 1996 data were interpolated from 1995 and 1997 first quarter data. Missing quarterly means for 1990 or 2002 were assumed equal to adjacent quarterly values. A valid quarterly mean was based on eight valid weeks. Annual means were based on data from four valid quarters.

CASTNet Database

The CASTNet database is available to the public via EPA's CASTNet data web page: www.epa.gov/castnet/data.html. The web site provides archives of the concentration and deposition data in quote comma delimited ASCII files compressed using the PKZIP compression utility. Fully validated data are generally available approximately ten months following collection. Other documentation for the network, including information about all CASTNet sites, can be found at the CASTNet home page: www.epa.gov/castnet/.

The different types of data are archived in various tables. For example, continuous data,

found in the METDATA table, consist of the following parameters:

- temperature
- difference in temperature between 2 and 9 meters
- solar radiation
- relative humidity
- ozone
- precipitation
- scalar wind speed
- vector wind speed
- wind direction
- standard deviation of the wind direction within the hour
- rate of flow through the filter pack
- surface wetness

> The CASTNet database contains archives of continuous meteorological, ozone, and flow data, concentrations measured on exposed filters, and MLM output of hourly, weekly, quarterly, and annual dry deposition fluxes.

Concentration data from the dry deposition network, found in the DRYCHEM and DRYCHEM_DAYNIGHT tables, consist of the following analytes: SO_4^{2-}, NO_3^-, NH_4^+, Ca^{2+}, Na^+, Mg^{2+}, and K^+ from the Teflon® filter, HNO_3 and SO_2 (as SO_4^{2-}) from the nylon filter, and SO_2 (as SO_4^{2-}) from the Whatman filters. These concentrations are maintained as micrograms per cubic meter ($\mu g/m^3$).

Tables containing output from the MLM (VELHR, VELWK, VELQR, and VELAN) hold simulated deposition velocities in centimeters per second (cm/sec) for SO_2, HNO_3, O_3, and particles (SO_4^{2-}, NO_3^-, and NH_4^+); concentrations for the six analytes in $\mu g/m^3$ (except for O_3 with units of ppb); and modeled estimates of dry deposition for the six analytes in kilograms per hectare (kg/ha).

SO$_2$ and NO$_x$ Emissions

SO_2 and NO_x emission data were obtained for Phase I and Phase II electric generating plants for 1990 through 2002. Title IV of the 1990 CAAA established the Acid Rain Program, which was designed to reduce emissions in two phases. Phase I ran from 1995 through 1999 and required substantive emission reductions from 435 large electric generating plants, involving approximately 2,000 individual units (DOE, 1997). Phase II began in 2000 and includes more than 2,000 generating stations.

Figure 1-4 presents information on trends in SO_2 and NO_x emissions. The bars on the chart represent emissions from Phase I and II generating stations over the period 1990 through 2002. The sharp decline in SO_2 emissions in 1995 was a result of utility compliance with Phase I of the Acid Rain Program. The SO_2 and NO_x data show an overall slow decline in emissions over the last five years.

> SO$_2$ emissions in the eastern United States declined sharply in 1995 as the result of utility compliance with Phase I of the Acid Rain Program. Emissions have declined over the last three years as emission reductions have been implemented at Phase II plants. NO$_x$ emissions remained essentially constant over the 13-year period although a decline has been observed over the last five years.

SO_2 emissions and SO_2 and SO_4^{2-} concentrations have declined significantly over the period 1990 through 2002. SO_2 concentrations track almost identically with emissions from Phase I electric utility units. SO_4^{2-} concentrations also track closely.
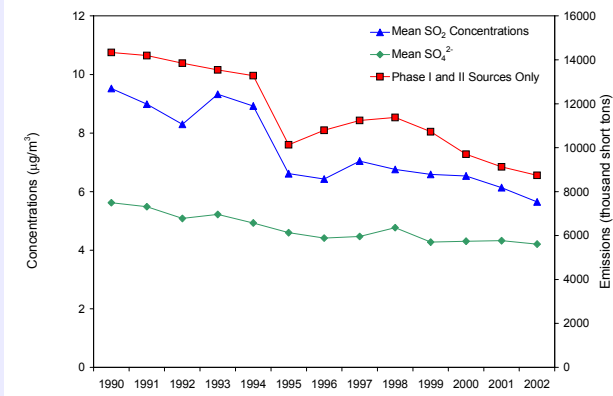

Figure 1-5 presents information on state-by-state total annual Phase I and Phase II utility SO_2 emissions for 2002. NO_x emissions are presented in Figure 1-6.

States with the highest utility SO_2 emissions are located along the Ohio River into Pennsylvania and also include North Carolina, Georgia, and Texas. High electric utility NO_x emissions are released from the same Ohio Valley states plus Illinois, Tennessee, Alabama, Florida, and Texas. The 34 eastern reference sites are located in the region where heaviest emissions take place (Figure 1-1).

Phase I and II utility SO_2 emissions by county for 2002 are presented in Figure 1-7. The utility emissions data were normalized by dividing the emission rate by the county area in square kilometers (km^2). Several major sources are located in western Pennsylvania, Alabama, and along the Ohio River and other major bodies of water.

Combined Phase I and II area-weighted NO_x emissions by county are provided in Figure 1-8. Major utility sources are located along the Ohio River and in western Pennsylvania with additional individual large units scattered across the eastern United States.
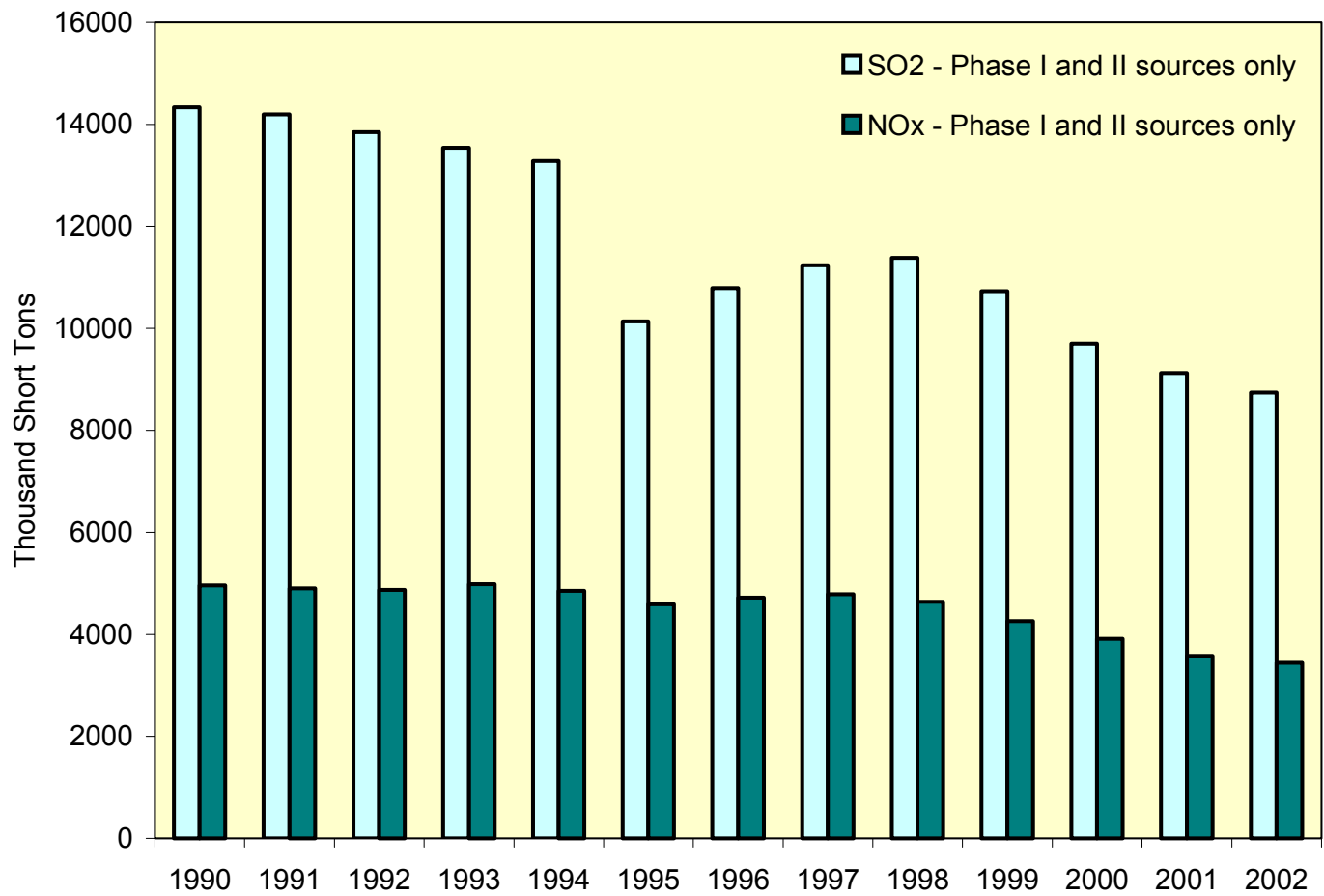
Figure 1-4. Trends in SO$_2$ and NO$_x$ Emissions for the Eastern United States

Figure 1-5. Annual Utility SO$_2$ Emissions (Phase I and Phase II Plants, only) for 2002

2002 Annual Emissions by State
(thousand short tons)
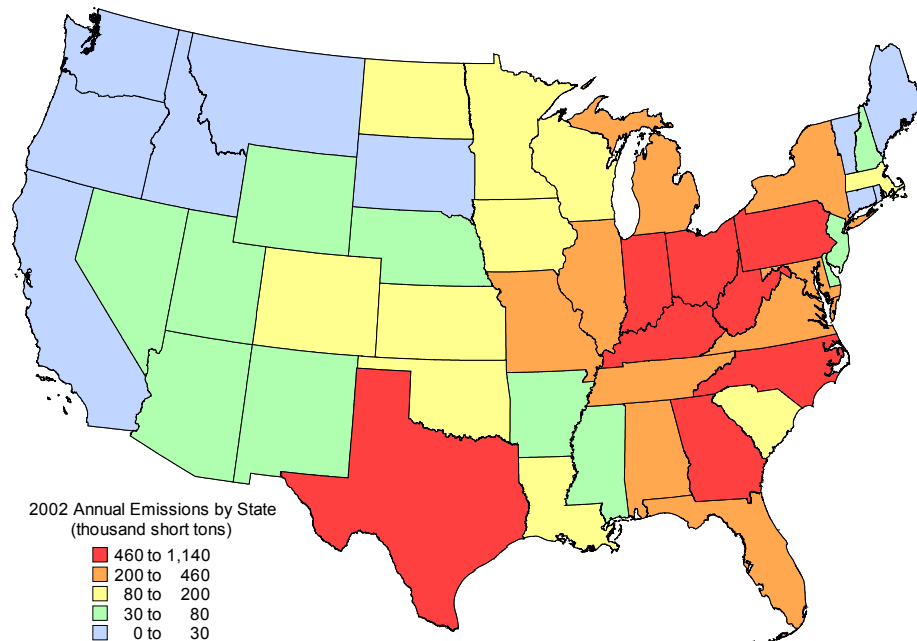- 460 to 1,140
- 200 to 460
- 80 to 200
- 30 to 80
- 0 to 30

Figure 1-6. Annual Utility NO$_x$ Emissions (Phase I and Phase II Plants, only) for 2002

2002 Annual Emissions by State
(thousand short tons)
- 157 to 369
- 89 to 157
- 76 to 89
- 16 to 76
- 0 to 16
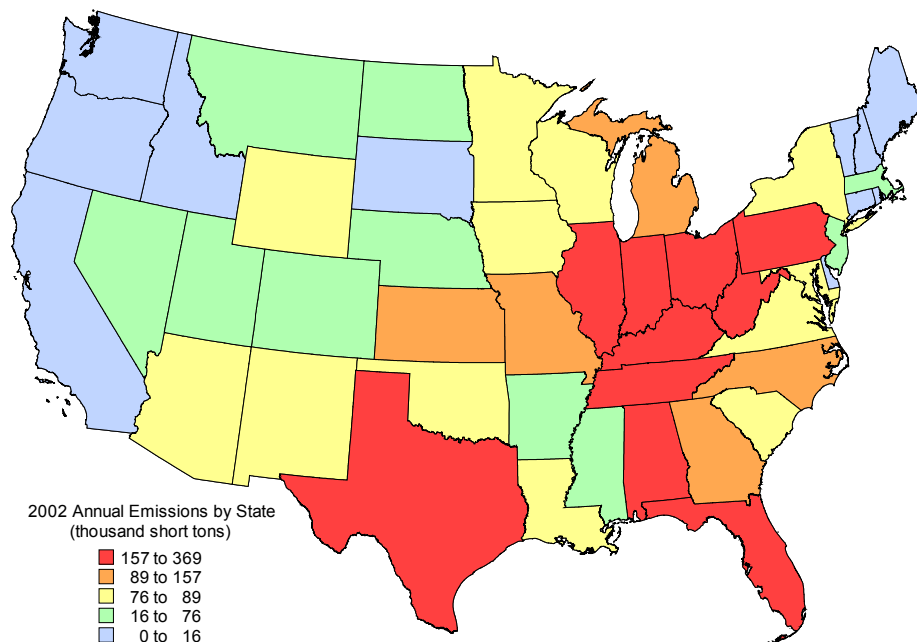
Figure 1-7. Annual Utility SO₂ Emissions (Phase I and Phase II Plants, only) for 2002 by County

2002 Annual Emissions by County
(short tons per square kilometer)

■	150 to 410
■	25 to 150
■	10 to 25
■	5 to 10
■	1 to 5
■	0 to 1
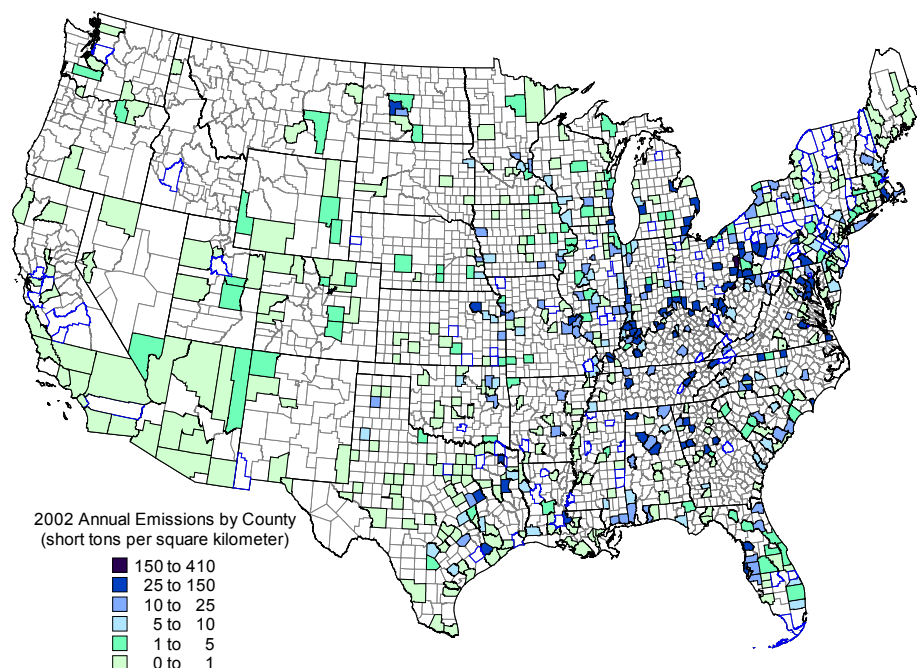
Figure 1-8. Annual Utility NOₓ Emissions (Phase I and Phase II Plants, only) for 2002 by County

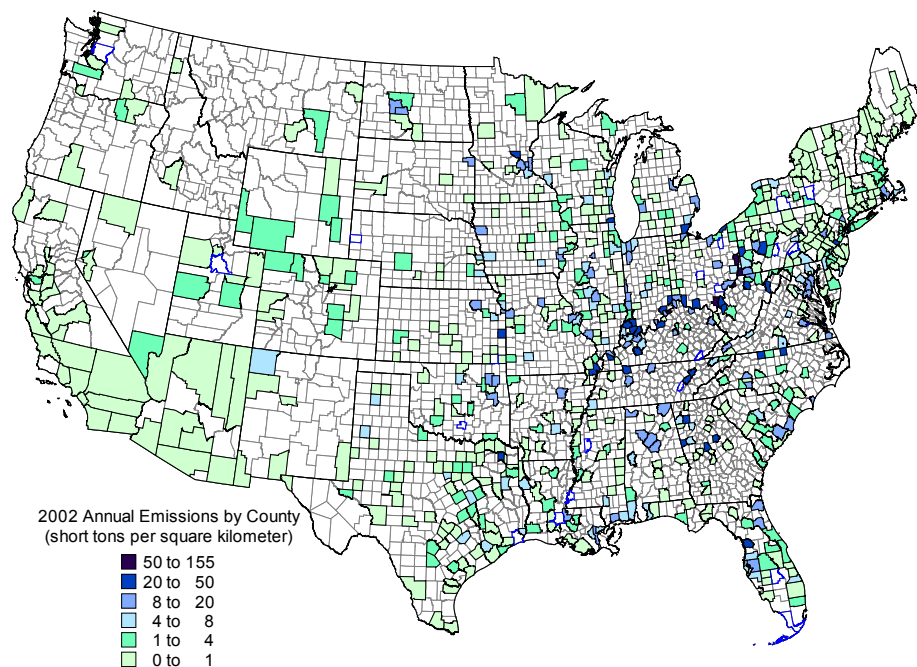2002 Annual Emissions by County
(short tons per square kilometer)

■	50 to 155
■	20 to 50
■	8 to 20
■	4 to 8
■	1 to 4
■	0 to 1

Note: A county with no shading indicates that either no electric utility plant operates in that county or no data are available.